# Air Quality Monitoring

## Slave Lake Area and Mitsue Industrial Park

**December 2005 – April 2006** **Final Report**

### Summary

Alberta Environment's mobile laboratory (MAML) and two stationary particulate matter monitors (TEOM) were used to conduct the current air quality survey. The main objective of the survey was to examine the influence of emissions from Mitsue industrial park and community based activities on the air quality in the town of Slave Lake, in particular the influence of pollutants present in wood-smoke. Mitsue industrial park contains four wood processing facilities that burn waste wood; in addition wood is used in the area for residential heating.

Elevated levels of carbon monoxide (CO), oxides of nitrogen ($NO_x$), polycyclic aromatic hydrocarbons (PAHs) and total suspended particles were measured during periods of low wind speed (less than 6 km/hr). These pollutants are constituents of smoke; their elevation is most likely due to the presence of smoke in the air. Elevated levels were observed downwind of facilities in Mitsue industrial park and in the town of Slave Lake. This being said, Alberta's Ambient Air Quality Objectives for CO and $NO_2$ (nitrogen dioxide, a fraction of $NO_x$) were not exceeded. While Alberta does not have one-hour average objectives for PAHs and total suspended particles, there are objectives for five of the pollutants monitored. The ***maximum one-hour*** concentrations were

- 6% of the one-hour objective for carbon monoxide;
- 8% of the one-hour objective for nitrogen dioxide;
- 3% of the one-hour objective for sulphur dioxide;
- 20% of the one-hour objective for hydrogen sulphide;
- <1% of the one-hour objective for ammonia; and
- 56% of the one-hour objective for ozone.

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Continuous particle concentration monitoring illustrated that the town of Slave Lake can be impacted by wood-smoke from the industrial park during specific meteorological conditions. These conditions were easterly and south-easterly winds and strong inversions, resulting in stagnant air. The results also indicated that emissions from community-based activities also make significant contribution. Influence of particulate matter on the air quality in Slave Lake was examined by determining the air quality index due to particle concentrations. The air quality was rated fair or poor for 1% of the sample time (29 days).

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## Introduction

Mitsue Lake industrial park is located about 8 km southeast of the town of Slave Lake. There are a variety of industries at the site including four wood processing facilities and two gas plants. The current study was conducted to investigate the impact of emissions fr. n the industrial park on the air quality. Of particular interest was the impact of smoke on the air quality in the area. There are two possible sources for smoke in the area: (a) scrap wood burning by wood processing facilities inside Mitsue Lake industrial park and, (b) the use of wood stoves for residential heating. It is likely that both these sources play some role in influencing air quality in the area. This study was designed to differentiate the impact of emissions from the Mitsue Lake industrial from emissions within the town.

Mitsue Lake industrial park and the town of Slave Lake are situated southwest of Martin Hills and northeast of Swan Hills. The wind in the area has two predominant directions: from the northwest quadrant or from southeast quadrant. Easterly winds were .pected to transport emissions from Mitsue Lake industrial park into town. Furthermore, the area experiences strong wintertime inversions preventing the dispersion of pollutants out of the area.

The study used two particulate samplers. One located in the town of Slave Lake and the other halfway between the town and Mitsue Lake industrial park. These instruments were operational between December 2005 and April 2006 and collected over 100 days of data at each of the two monitoring sites. In addition, the department's mobile laboratory (MAML) collected 17 hours of data over 4 days, in December 2005 and March 2006.

## Monitoring method and location

Special air quality surveys by Alberta Environment typically use the mobile air quality monitoring laboratory (MAML). The MAML is equipped to measure a suite of pollutants. These include ammonia, carbon monoxide, hydrocarbons, oxides of nitrogen, ozone, course and fine particulate matter, reduced sulphur compounds and sulphur dioxide. These parameters are measured simultaneously to give a "snap shot" of air quality in time and place. Data collected were averaged into one-hour intervals and used in discussing the results. Further description of the MAML is found in Appendix B. In addition, two Tapered Element Oscillating Microbalances (TEOMs) were used to sample fine particles with aerodynamic diameter less than 2.5 micrometer (μm). The TEOM is a continuous particle sampler and allows the determination of one-hour average concentrations.

The two TEOMs were located such that the results could be used to differentiate sources upwind of the town of Slave Lake from sources within the town. One TEOM was located in the town of Slave Lake, **Site 1a.** This TEOM was placed in a residential area at the north end of town and would have been impacted by emissions from community based activities and sources upwind of the town. In the case of easterly winds this would include emissions from Mitsue Lake industrial park. The second TEOM was located between the town and Mitsue Lake industrial park, about 6 km east of Slave Lake. For easterly and possibly south-easterly winds samples at this site would have likely been influenced by emissions from Mitsue Lake industrial park. Data collection started in December 2005 in the town of Slave Lake (**Site 1a**) and January 2006 outside the town (**Site 2**). Sampling was completed at both locations in April 2006. The two instruments were operational 82% of the time collecting over 100 hours of data at each location.

Air quality monitoring using the MAML was performed at five locations. A description of the MAML can be found in Appendix B. Two of the sample locations were within the town of Slave Lake. Measurements were conducted in the south and north ends of town (**Site 1a and 1b**). Data collected at these two locations were very similar, thus grouped and referred to as **Site 1**. The remaining sites were within the Mitsue Lake industrial park. Samples were collected downwind from the industrial area as a whole (**Site 3**), the Acclaim gas plant (**Site 4**) and Alberta Plywood (**Site 5**). Monitoring was conducted on two consecutive days in December 2005 and March 2006.

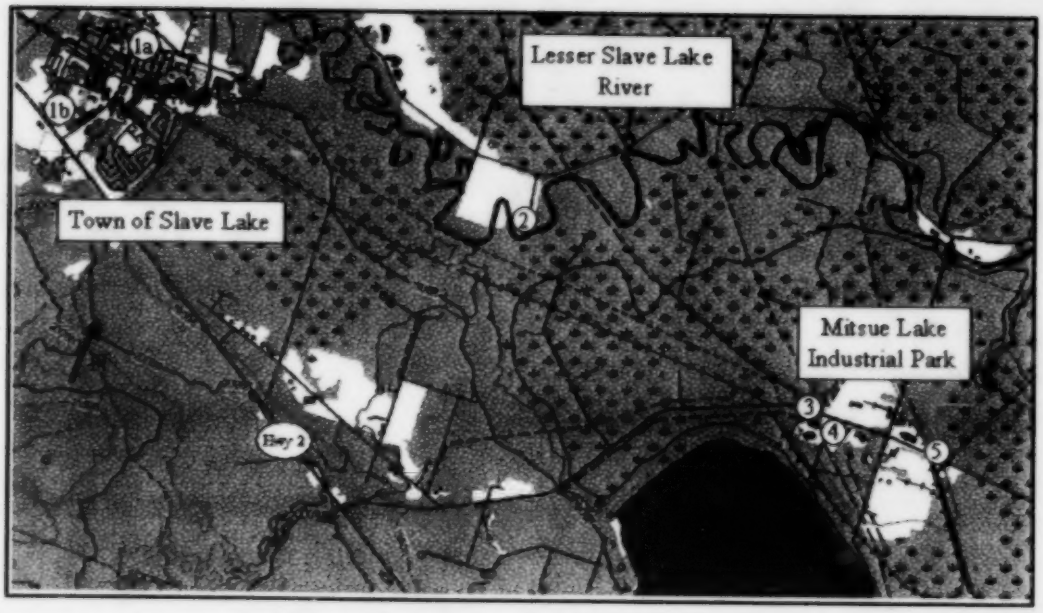
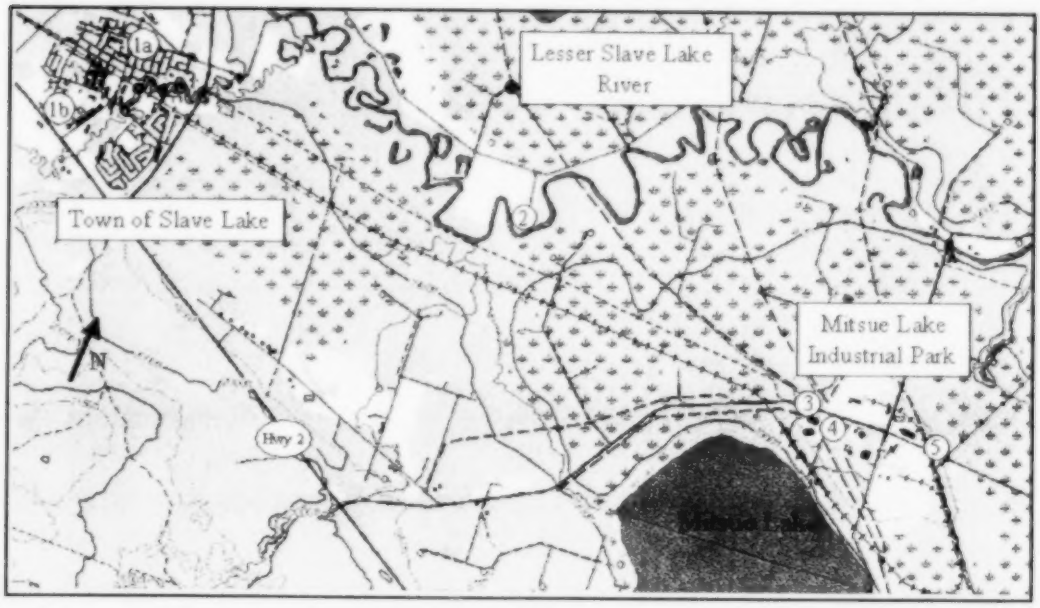



**Figure 1: Map of monitoring locations**

**Table 1: Descriptions of monitoring locations**

| Site | Description | Method |
|---|---|---|
| 1a | Residential area in the north end of the town of Slave Lake, 6th avenue NW | TEOM and MAML |
| 1b | Town of Slave Lake, 14th Ave SW | MAML |
| 2 | About 6 km east of the town Slave Lake and northwest of Mitsue Lake industrial park | TEOM |
| 3 | Entrance to Mitsue Lake industrial park | MAML |
| 4 | Downwind of Acclaim gas plant (Mitsue Lake industrial park) | MAML |
| 5 | Downwind of Alberta Plywood (Mitsue Lake industrial park) | MAML |

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(A)

(B)

**Figure 2: Photographs depicting particle ($PM_{2.5}$) monitoring sites. (A) Site 1a was located in the town of Slave Lake, on Sustainable Resource Development (SRD) compound. Shown are the meteorological tower and the box containing monitoring instruments. (B) Site 2 was located at a clearing for an oil well injection site.**

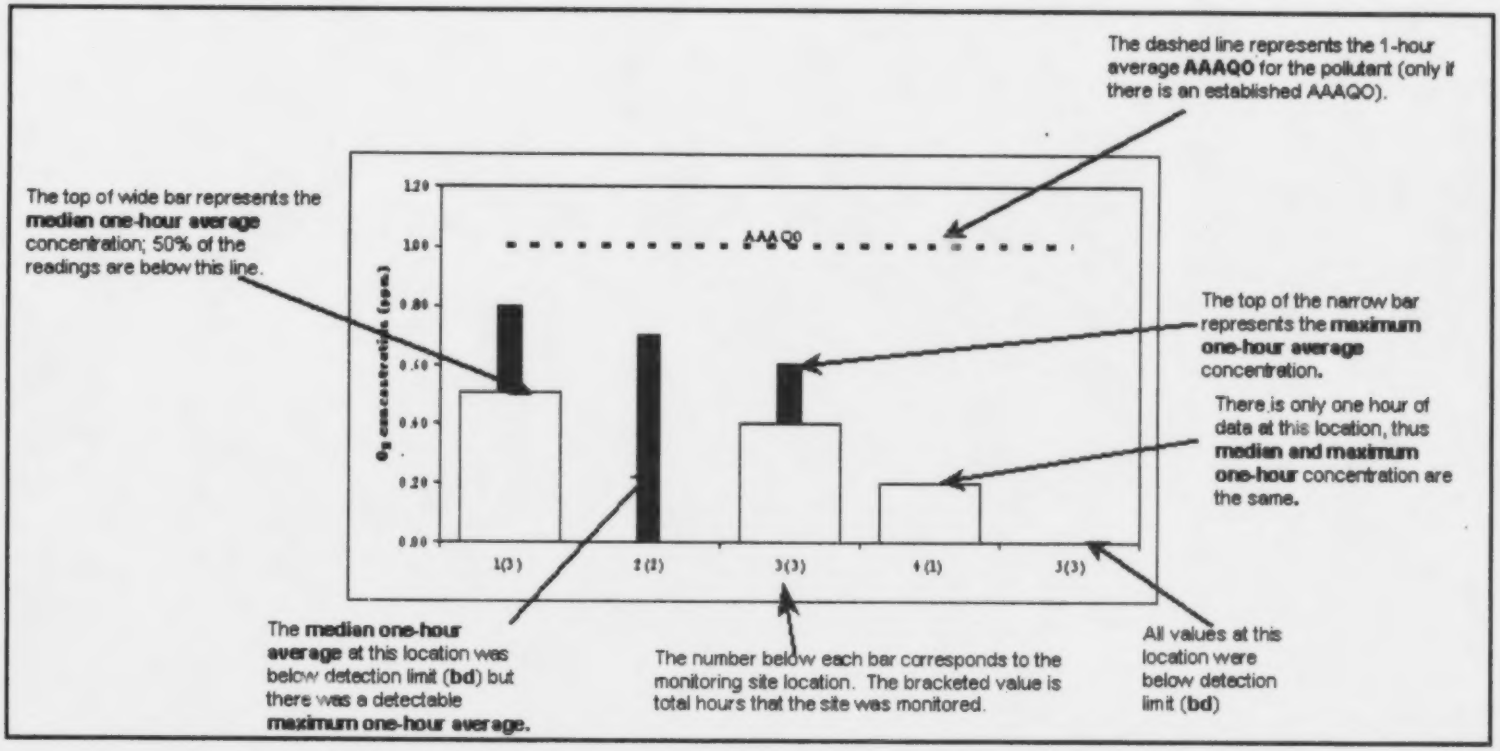
The dashed line represents the 1-hour average **AAAQO** for the pollutant (only if there is an established AAAQO).
The top of wide bar represents the **median one-hour average** concentration; 50% of the readings are below this line.
AAAQO
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1(3)
2(1)
3(3)
4(1)
5(3)
The top of the narrow bar represents the **maximum one-hour average** concentration.
There is only one hour of data at this location, thus **median and maximum one-hour** concentration are the same.
The **median one-hour average** at this location was below detection limit (**bd**) but there was a detectable **maximum one-hour average.**
The number below each bar corresponds to the monitoring site location. The bracketed value is total hours that the site was monitored.
All values at this location were below detection limit (**bd**)

**Figure 3: A key for interpreting the figures in the following section.**

## Results and Discussion

The following sections will discuss the results obtained from instrumentation onboard the MAML and from the two TEOMs. Instruments onboard the MAML monitor for a variety of pollutants, which are listed in the section on *Monitoring Methods*. Only the pollutants relevant for the current study will be discussed in this section, namely total hydrocarbons, carbon monoxide, oxides of nitrogen, polycyclic aromatic hydrocarbons, and particulate matter. When applicable, one-hour average concentrations will be compared to Alberta's Ambient Air Quality Objectives (AAAQO). A description of AAAQO can be found in Appendix B. The one-hour average concentrations for all of the pollutants monitored are listed in Appendix A (Table A1).

Results are summarized graphically using the maximum and median one-hour concentrations. Figure 3 is a key for interpreting the graphical results presented in the following sections. Results from continuous monitoring of particulates, conducted using the two stationary monitoring instruments (TEOMs), will follow the MAML data discussion.

### *Meteorological conditions*

Wind speed and direction were measured at both **Site 1a** and **2** for a period of about 4 months. For many of the sample days the wind speed was low, on average less than 6 km/hr during the morning and evening hours. Wind speed less than 6 km/hr was measured 56% of the time, with almost half of being less than 1 km/hr. These results suggest stagnant air, possibly conducive to wintertime inversions. Such conditions limit the dispersion of emissions. Flows from the east-southeast and southeast formed the more predominant wind directions (Figure 4). Such a flow would place the town of Slave Lake downwind of Mitsue industrial park. However since the wind speed for a significant fraction of the sample times was low, local sources could also have contributed to the level of pollutants measured in town.

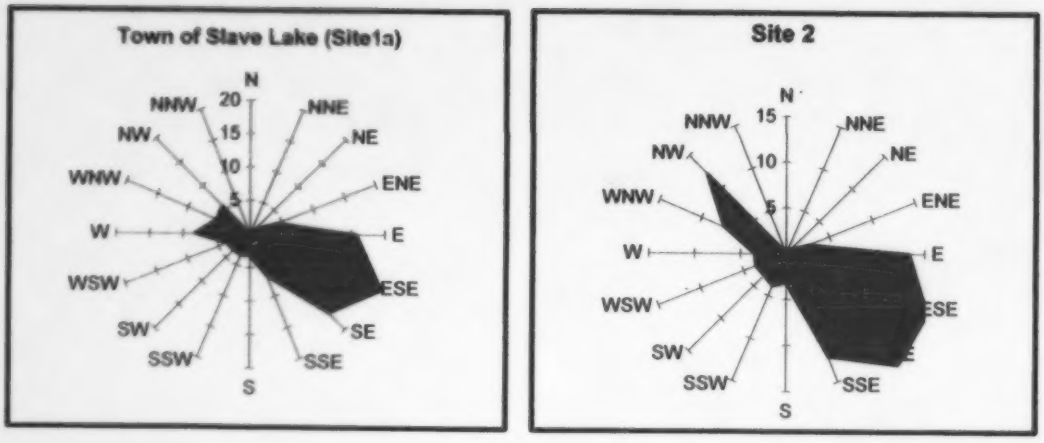


**Figure 4: Wind rose for data collected at the two particle monitoring sites. Over 1000 hours of data was used to generate the figures. The average wind speeds at Site 1a and Site 2 were 6 km/hr. East-south east (Site 1a) and southeast (Site 2) were the prominent wind directions. The radial axis on these figures indicates percentage of data.**

## *Total Hydrocarbons (Methane and Reactive Hydrocarbon)*

The term *total hydrocarbons* (THC) refers to a broad family of compounds that contain carbon and hydrogen atoms. Included in this group is methane ($CH_4$), a non-reactive hydrocarbon. $CH_4$ is the most abundant hydrocarbon in the atmosphere. As a result, THC often largely consists of $CH_4$, making concentrations of $CH_4$ equivalent to THC concentrations. In Alberta, the background THC level is about 2 ppm. The other fraction of THC are reactive hydrocarbons (RHC) also know as non-methane hydrocarbons. RHC are important because they can react in the atmosphere to form ozone. Furthermore, at high concentrations, some RHC can be toxic to humans, animals and vegetation. Although RHC can be composed of several different hydrocarbons, onboard the MAML RHC is measured as the combined concentration. Some major sources of hydrocarbons include oil and gas processing and handling, vehicle emissions and vegetation.

With the exception of the maximum one-hour average concentration measured at **Site 4,** total hydrocarbon concentrations were almost entirely composed of $CH_4$ (Figures 5 and 6). Furthermore, hydrocarbon concentrations were only marginally higher than the typically observed background level (~ 2 ppm). The one notable exception was the maximum one-hour average measured downwind of Acclaim gas plant (**Site 4**). The maximum one-hour average total hydrocarbon concentration at this site was 6.1 ppm. Furthermore, reactive hydrocarbons composed 67% of the total hydrocarbons (Figure 7); the only sample time when RHC were

notably above the detection limit of instrumentation onboard the MAML. Elevated concentrations were measured at a time when the wind speed was low (less than 5 km/hr) preventing the dispersion of emitted pollutants. Fugitive emission from Acclaim gas plant is the likely source of the elevated hydrocarbon measurements. The somewhat elevated THC concentration downwind of Alberta Plywood (**Site 5**) was almost entirely composed of $CH_4$.

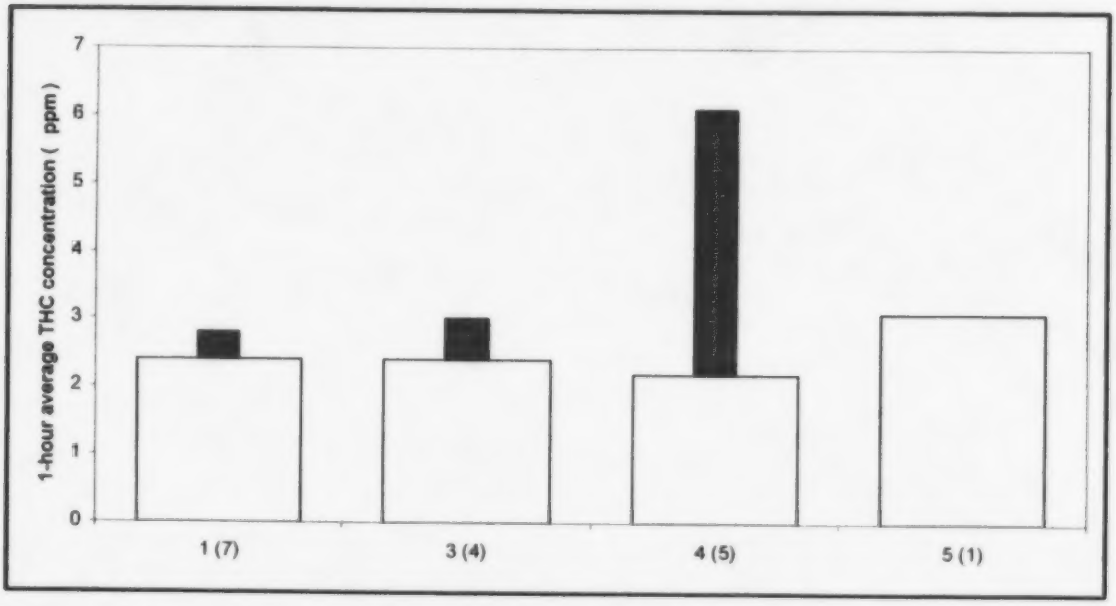


**Figure 5: Maximum and median one-hour average concentrations for Total Hydrocarbons. There was only a single hour of measurement at Site 5; the result presented is the average for that hour.**

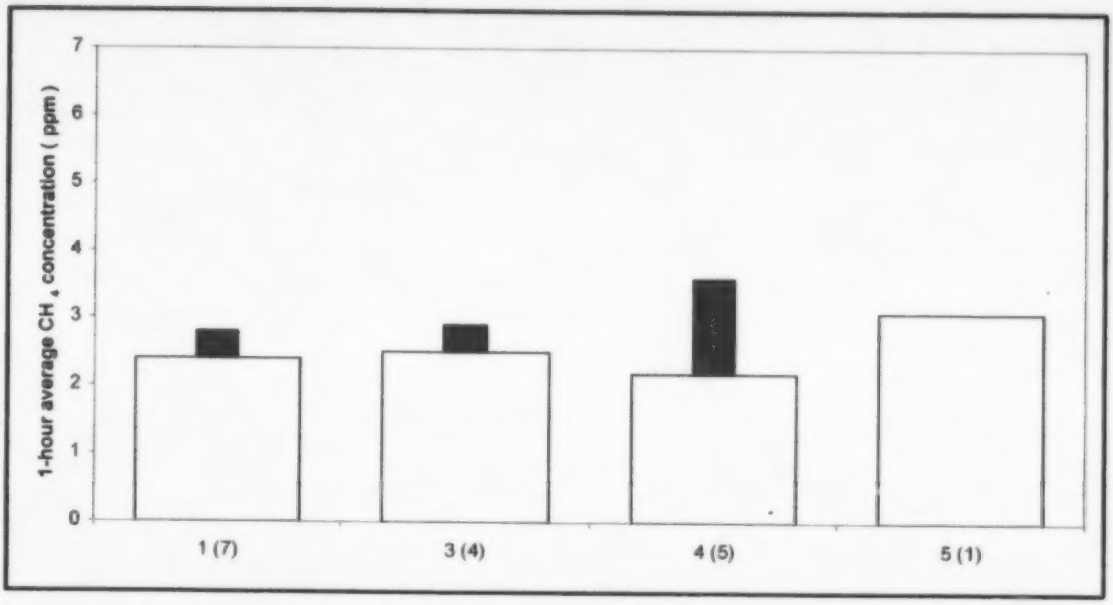


**Figure 6: Maximum and median one-hour average concentrations for methane. There was only a single hour of measurement at Site 5; the result presented is the average for that hour.**

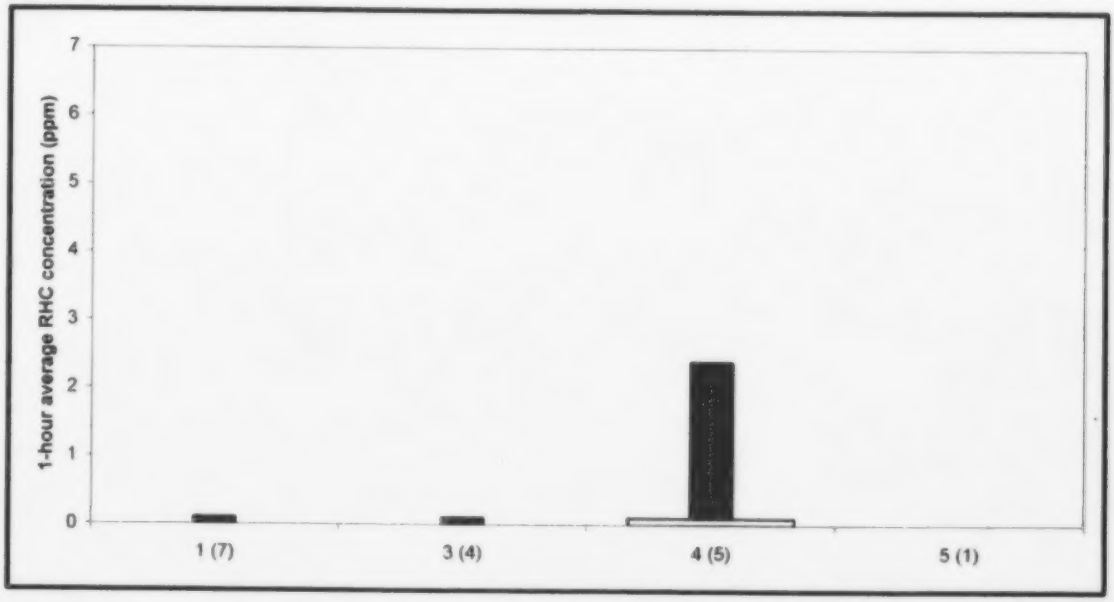


**Figure 7: Maximum and median one-hour average concentrations of Reactive Hydrocarbons. There was only a single hour of measurement at Site 5; the one-hour average concentration at this time was below detection limit. The median one-hour average concentrations at Site 1 and 3 were also below detection limit.**

## *Carbon Monoxide (CO)*

Carbon monoxide (CO) is a by-product of incomplete combustion. Hot dry fires with sufficient supply of oxygen produce carbon dioxide ($CO_2$), but when these conditions are not met carbon monoxide and other pollutants such as oxides of nitrogen, methane and particulate matter are produced. Emissions from waste wood burning inside the Mitsue industrial park is likely to contain carbon monoxide.

One-hour average CO concentrations in and around the Slave Lake ranged from 0.1 to 0.8 ppm. These concentrations were well below Alberta's Ambient Air Quality Objective (AAAQO) of 13 ppm. In general, CO levels in the current survey were comparable to other MAML surveys around Alberta. The median concentrations for various MAML surveys are compared in Table A3. However, a somewhat elevated one-hour average concentration of 0.8 ppm was measured in the town of Slave Lake (**Site 1**), downwind of the industrial park (**Site 3**) and downwind of Alberta plywood (**Site 5**) (Figure 8). The maximum one-hour average CO concentrations were observed alongside elevated oxides of nitrogen and polycyclic aromatic hydrocarbons. Thus it is likely that the samples were influenced by smoke from wood-burning. Wood-burning emissions from both household and industrial use most probably contributed to the measured CO concentrations, however the levels emitted were not significant.

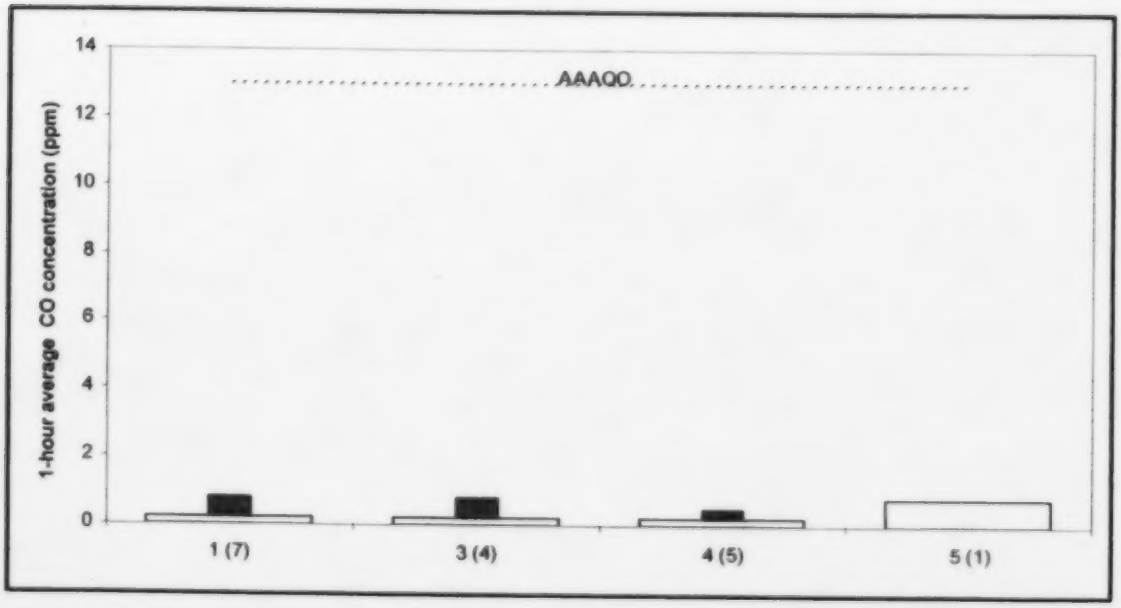


**Figure 8: Median and maximum one-hour average concentrations for carbon monoxide. There was only a single hour of measurement at Site 5; the result presented is the average for that hour.**

### *Oxides of Nitrogen ($NO_x$)*

The sum of nitrogen dioxide ($NO_2$) and nitric oxide (NO) constitute oxides of nitrogen ($NO_x$). In Alberta transportation is the major source of $NO_x$. However, $NO_x$ is also emitted during wood burning. High NO to $NO_2$ ratios are typically associated with relatively fresh emission plumes; $NO_2$ is formed as NO reacts with ozone when the plume moves farther downwind and ages.

Figure 9 and 10 illustrate the median and maximum NO and $NO_2$ concentrations measured during the current study. The y-axis for these figures are equivalent to facilitate comparison. During periods of elevated concentrations, NO was the greater fraction of $NO_x$. This implies relatively fresh emissions likely from a nearby source. One-hour average $NO_2$ concentrations ranged from 0.004 to 0.017 ppm. Comparatively, one-hour average NO concentrations ranged from 0.002 to 0.064 ppm. Alberta has an air quality objective for $NO_2$ of 0.212 ppm. Although elevated relative to most other MAML studies (Table A3), $NO_2$ concentrations measured during the Slave Lake study did not exceed the objective.

The highest concentrations of NO and $NO_2$ were measured concurrently in the town of Slave Lake (**Site 1**), at a time when smoke was evident in the area (Table A2). The wind speed was low (less than 2.5 km/hr), thus the smoke and elevated $NO_x$ likely have contributions from wood stove use in residential heating. This being said, equally evaluated levels were also measured in Mitsue industrial park (**Sites 3-5**) as indicated in Figures 9 and 10. Thus, transport from the industrial park is also possible.

Compared to other MAML surveys in rural areas, the $NO_2$ concentrations measured during the Slave Lake study were one of the highest. However, the $NO_2$ concentrations in this survey were not as elevated as those observed in large urban centres (recall that transportation is a major source of $NO_x$). There is evidence that insufficient levels of ozone may have limited the conversion of NO to $NO_2$. Ozone concentrations during winter are typically low due to the lack of available solar radiation. However, concentrations during the current study were especially low. Ozone concentrations during the winter sample months ranged from below detection limit to 0.004 ppm (see Table A3 for comparison with other studies). Note for example ozone and $NO_2$ levels measured during *Tolko High Prairie* study, a study carried out during the same season as the current study (Table A3). In the Tolko study, ozone levels were higher;

furthermore $NO_2$ levels were lower, with a median one-hour average $NO_2$ concentration of 0.018 ppm.

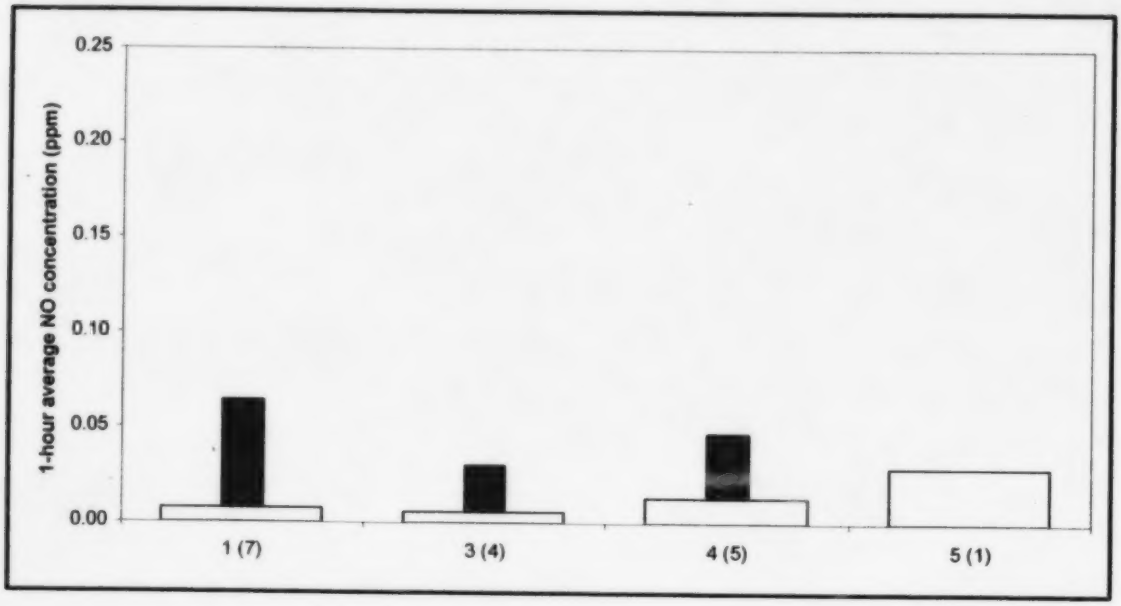


**Figure 9: Median and maximum one-hour average concentrations for nitric oxide. There was only a single hour of measurement at Site 5; the result presented is the average for that hour.**

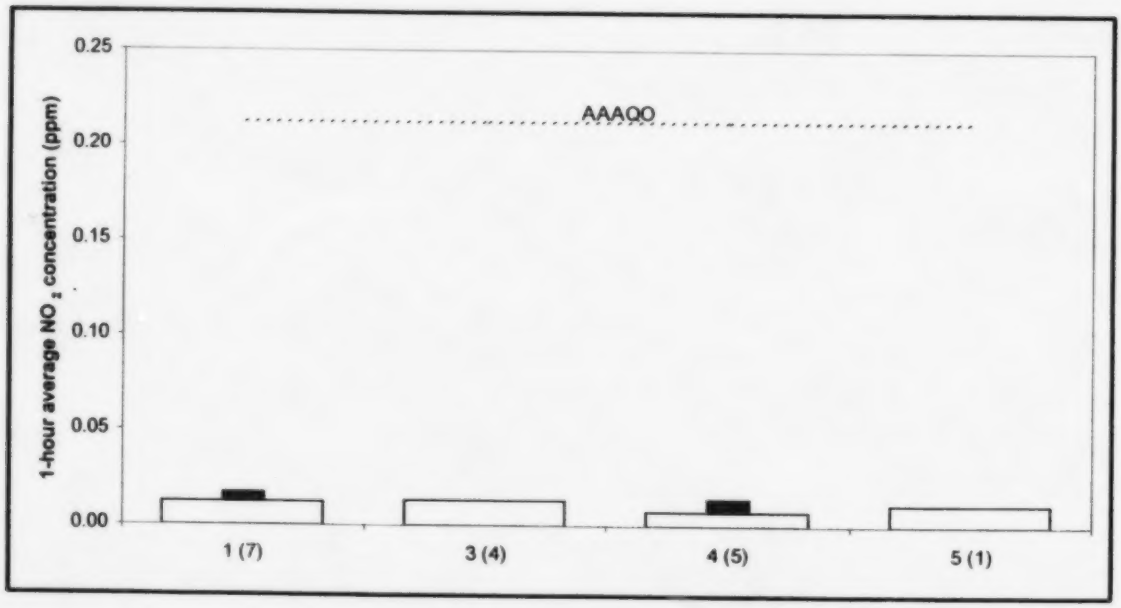


**Figure 10: Median and maximum one-hour average concentrations for nitrogen dioxide. There was only a single hour of measurement at Site 5; the result presented is the average for that hour.**

## *Polycyclic aromatic hydrocarbons (PAHs)*

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds consisting of two or more benzene rings. While vehicle exhaust is one source of PAHs, emissions from incomplete combustion are a significant source of atmospheric PAHs; these include wood-smoke from residential heating, industry and forest fires. PAHs can be found as a gas or condensed onto particles. Larger PAHs (containing more benzene rings) tend to attach onto particles. It is these types of PAHs that are measured by the MAML. PAHs usually occur as complex mixtures rather than single compounds, each with varying level of toxicity.

Figure 11 summarizes the one-hour average PAHs concentrations measured by the instrument on-board the MAML. Typically, background concentration of PAHs in rural areas is about 1 $ng/m^3$. The median concentrations measured at the most recent MAML surveys are comparable to background levels (Table A3). The median for the current study was 8 $ng/m^3$. Although higher than most MAML studies, this level was lower than the median measured during the Calder yard study in north central Edmonton. Samples from the Calder yard study were highly influenced by emissions from diesel trucks. Elevated PAHs concentrations for the current study were measured at almost all the sites as indicated by the maximum and average concentrations. The highest one-hour average concentration of 32 $ng/m^3$ was measured downwind of the Mitsue industrial park as a whole (**Site 3**). The highest concentration measured in the town of Slave Lake was 19 $ng/m^3$. Elevated concentrations in town were measured at the same time as elevated $NO_x$ concentrations and meteorological conditions prevented the dispersion of pollutants. Elevated PAHs concentrations in Slave Lake and area are most likely due to the presence of wood-smoke.

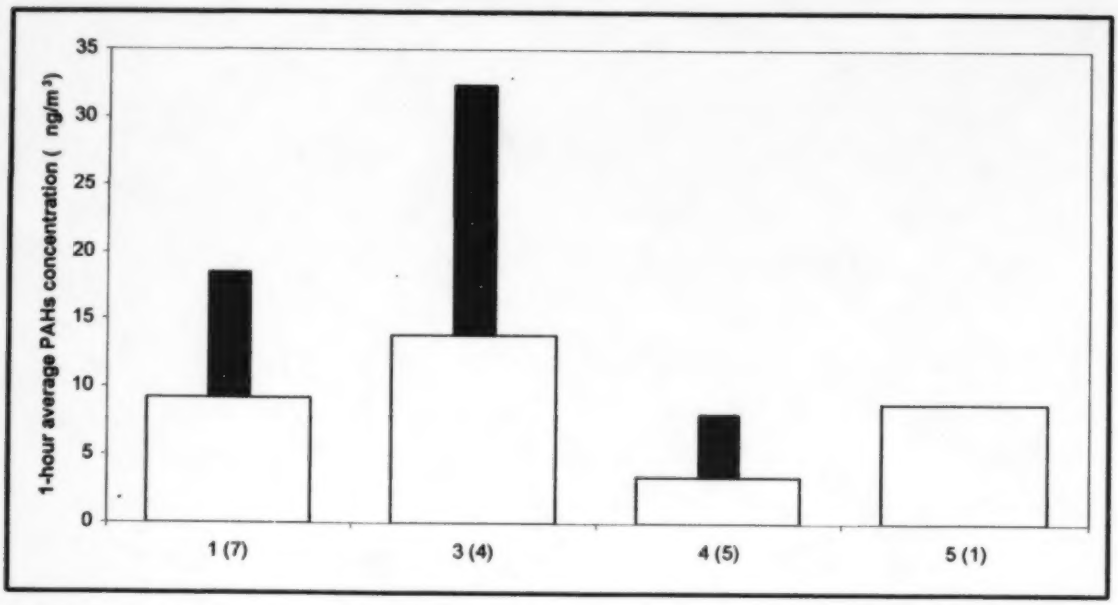


**Figure 11: Median and maximum one hour average concentrations for PAHs. There was only a single hour of measurement at Site 5; the result presented is the average for that hour.**

## *Particulate Matter (TSP, $PM_{10}$ and $PM_{2.5}$)*

Particles in the atmosphere are grouped according to their size. Size categorisation is useful as particles of different size affect the respiratory system differently. Particles less than 10 micrometers (μm) in aerodynamic diameter ($PM_{10}$) can be inhaled into the respiratory tract. Particulate matter less than 2.5 μm in aerodynamic diameter ($PM_{2.5}$) are small enough to penetrate even further into the lungs. $PM_{2.5}$ may form in the atmosphere through the reaction of other pollutants and/or arise from combustion sources such as vehicle exhaust, industrial emissions and wood burning. A fraction of $PM_{10}$ is generated mechanically and is composed of soil dust, road dust, agricultural dust (e.g., generated through harvesting). In addition, smoke from forest fires and wood burning, vehicle exhaust and industrial emissions are also sources of $PM_{10}$. Total suspended particulates (TSP) range in size from 0.001 to 500 μm; this group includes both $PM_{10}$ and $PM_{2.5}$. The fraction of TSP not included in $PM_{10}$ (greater than 10 μm) is largely produced through mechanical processes. Particulate matter from mechanical processes (road and soil dust) was not expected to make significant contribution to the sample. For much of the sample time the ground at the sample sites was frozen.

One-hour average Total Suspended Particles concentrations ranged from 86 $\mu g/m^3$ (measured downwind from Alberta plywood) to 4 $\mu g/m^3$ (measured in the town of Slave Lake). It should also be noted that one-hour average concentrations as high as 38 $\mu g/m^3$ were also observed for two sample hours in the town of Slave Lake (**Site 1**, Figure 12). These observations indicate that particle concentrations in the area can be highly variable. One notable difference between the sample hours with the lowest concentrations and that of the elevated concentrations was the decrease in wind speed for the latter (Table A1 and A2).

The relative concentrations of $PM_{10}$ was similar to TSP. To facilitate comparison, the figures summarizing TSP, $PM_{10}$ and $PM_{2.5}$ concentrations as measured by instruments on-board the MAML have equivalent scales. One-hour average $PM_{10}$ concentration ranged from 4 to 38 $\mu g/m^3$. On average, $PM_{10}$ mass fraction formed 70% of the TSP. $PM_{2.5}$ concentrations did not significantly differ by site. A more in depth discussion of this size range will follow in the next section.

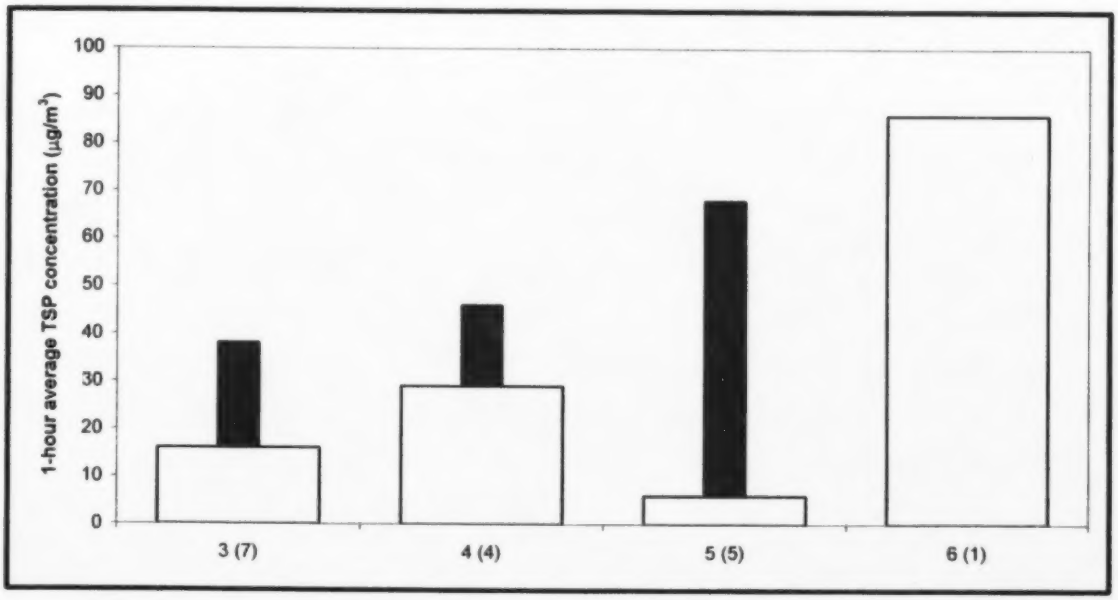


**Figure 12: Median and maximum one-hour average concentrations for Total Suspended Particle. There was only a single hour of measurement at Site 5; the result presented is the average for that hour.**

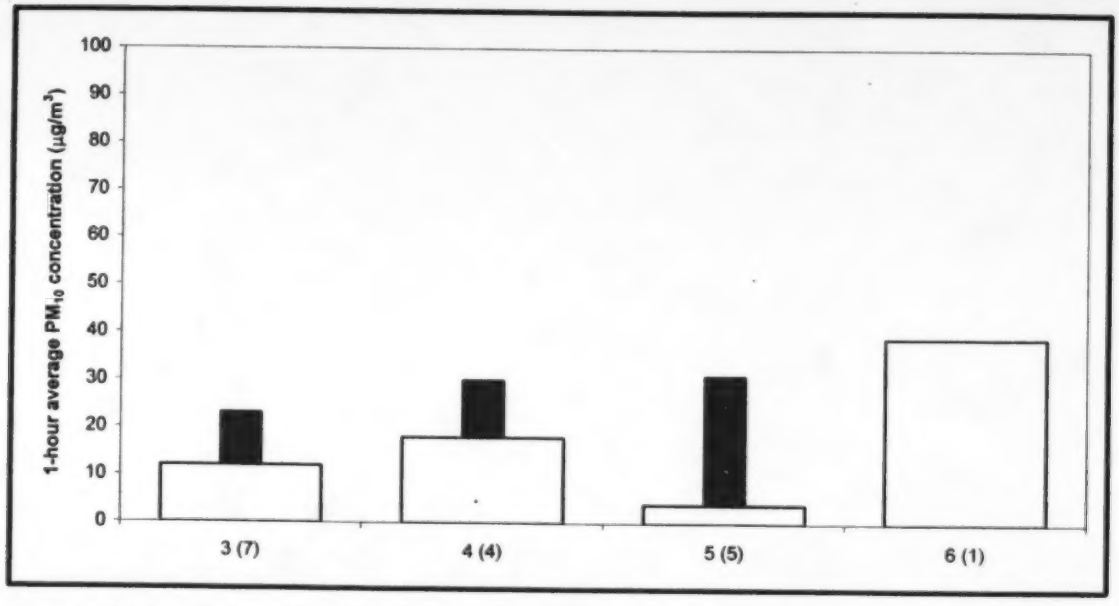


**Figure 13: Median and maximum one-hour average concentrations for $PM_{10}$. There was only a single hour of measurement at Site 5; the result presented is the average for that hour.**

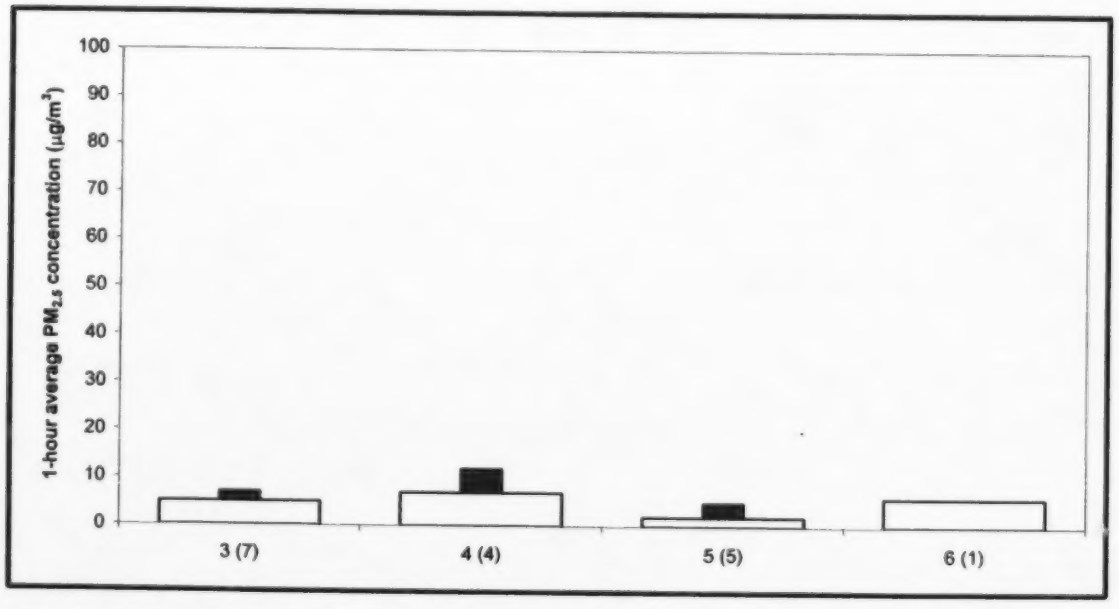


**Figure 14: Median and maximum one-hour average concentrations for $PM_{2.5}$. There was only a single hour of measurement at Site 5; the result presented is the average for that hour.**

### *Continuous measurement of $PM_{2.5}$ concentrations in the town of Slave Lake (Site 1a) and Site 2*

Particulate concentrations were measured inside and outside the town of Slave Lake for several months in an effort to differentiate contribution from community-based activity and emissions from Mitsue industrial park. The measurement outside the town (**Site 2**) was located between the industrial park and the town (Figure 1). The predominant wind direction (Figure 4), places **Site 2** upwind of the town of Slave Lake.

Figure 15 compares particle concentrations at **Site 1a** and **Site 2**. This comparison illustrates that there are segments of the sample period when concentrations at the two sites are comparable (A and to some extent C in Figure 15). At these times, particle concentration and variation in time at **Site1a** (town of Slave Lake) had a lot of similarities to measurement at **Site 2** (upwind). Concentrations measured at **Site 2** are likely due to emissions at the industrial park, as there were no other known significant sources in the sample area. The similarity in particle concentration and temporal variation between the two sites implies that the same source and/or processes affected both **Site 2** and **Site 1a.** The most likely source area is Mitsue industrial park.

Although some level of correlation was observed for particle concentrations at the two sites, short-term increases in particle concentrations at **Site 1a** (town of Slave Lake) were without corresponding increase in concentration at **Site 2**. This is clearly evident in Figures 15A and C. In fact these increases were some of the highest concentrations measured at **Site 1a**. Elevated particulate concentrations at this site were measured when the wind speed was lower than ~2 km/hr (calm); thus local sources are most likely contributors. These results indicate that *in addition* to upwind sources, particle concentrations in the town of Slave Lake were also influenced by community-based activities within the town. Possible sources include residential wood stoves and to some extent automobile emissions.

For a twelve-day period (March 14 – 26) particle concentration at the upwind site (**Site 2**) was noticeably higher than measured in the town of Slave Lake (Figure 15B). A change in the meteorological pattern was noted, namely a shift in the daily pattern of wind speed. The wind speed on these days remained above 5 km/hr through out the day. Recall that for the other sample days wind was calm for much of the day. Furthermore, the predominant wind direction shifted from easterly to south-easterly. Higher wind speed on these days implies the absence of an inversion or stagnant air, promoting the dispersion of pollutants. Also, higher wind speeds

would result in increased likelihood that particles would be removed (deposited) from the air before reaching **Site 1a**. Thus in the absence of stable air (or an inversion), the influence of emissions from industrial park on the town of Slave Lake is minimal.

### *Influence of particulate matter on the Quality of air*

Particulate concentrations were measured at two sites on a continuous basis for about four months. In general, particle concentrations were highly variable with maximum one-hour concentrations reaching 90 $\mu g/m^3$. Alberta does not have an air quality objective for one-hour average $PM_{2.5}$. Canada Wide Standard (CWS) for $PM_{2.5}$ has in the past been used as a benchmark to evaluate concentrations. However, this standard is applicable to 24-hour averages. In order to evaluate the impact of $PM_{2.5}$ on the air quality in the town of Slave Lake, the Air Quality Index[1] ***due to particulate matter*** was determined for the period of the study. At the Slave Lake sample site (**Site 1a**), the air quality rated ***fair*** for 28 sample hours and ***poor*** for one sample hour; these sample times were distributed over 12 days and formed about 1% of the data collected. Although forming a small fraction of the data, this finding illustrates that the air quality in the town of Slave Lake can be affected by elevated concentration of particles. As discussed in the previous section possible sources include industrial waste wood burning and residential heating.

[1] At Alberta's air quality monitoring stations, this index is calculated for five parameters. The highest of these five values is then used to indicate the quality of air. In this section however the index value is calculated only for particulate matter. A detailed explanation of the Air Quality Index and the method of calculation can be found at http://www.casadata.org/airqualityindex/.

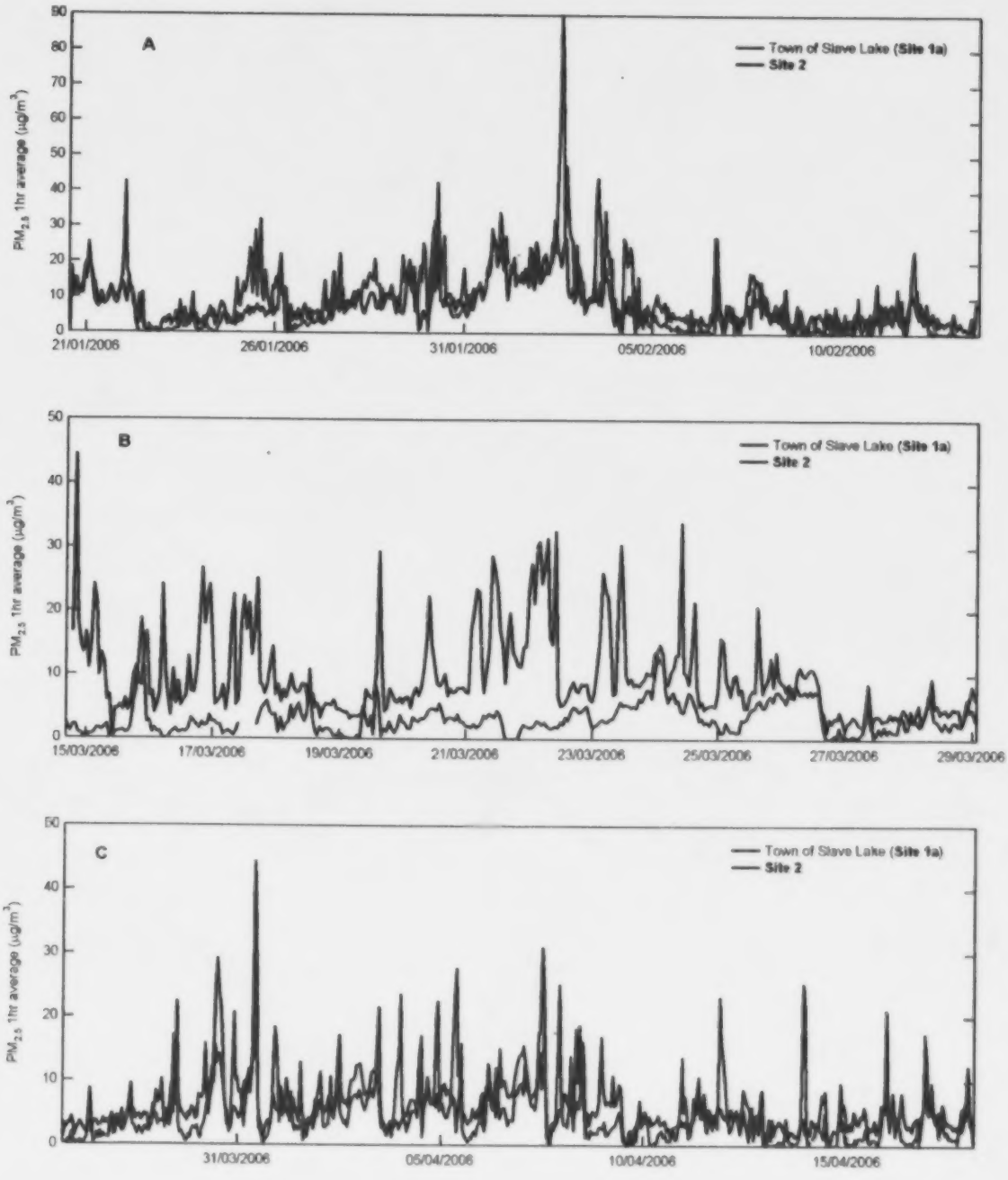


**Figure 15: One-hour average $PM_{2.5}$ concentrations measured inside the town of Slave Lake (Site 2) and the predominantly upwind site (Site 2) located between the town and Mitsue Lake industrial park.**

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